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APPLICATION OF A TWO FLUID THEORETICAL PLASMA TRANSPORT MODEL ON CURRENT TOKAMAK REACTOR DESIGNS*

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The TIBER II study began in 1985 to determine the physical parameters and cost of the minimum-size tokamak device suitable as an Engineering Test Reactor for the magnetic fusion program [1].

The TIBER II design is based on the empirical scaling law for the plasma energy confinement time known as Kaye-Goldston scaling [2]. This empirical scaling law comes from trends observed on tokamaks with auxiliary heating. In these experiments the electron temperature was typically a few keV, whereas the TIBER II reactor is designed for the much higher electron temperatures needed for efficient steady-state current drive (nominally 25 keV average). As no experiment has yet achieved electron temperatures above 6 to 7 keV, the validity of the Kaye-Goldston scaling law at the high electron temperatures needed for TIBER II remains an open question.

Lacking experimental guidance, it is necessary to turn to theory. Recently, theoretical transport models have been developed that give some support to the empirical trends. These models, based on microinstabilities, do show unfavorable scaling with electron temperature but they also resemble the Kaye-Goldston scaling used in the TIBER II design.

In this work, we apply the new theoretical transport models to TIBER II design calculations and also compare the results with recent experimental data in large tokamaks (TFTR, JET). We follow the approach of Tang [3]. However, we extend his method to a two-fluid model treating ions and electrons separately. This allows for different ion and electron temperatures, as in recent low-density experiments in TFTR, and in the TIBER II design itself.

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DESCRIPTION OF WORK

The work is divided into two parts: (1) Development of the theoretical transport model and (2) calibration against experiments and application to TIBER II.

In part 1, a two-fluid transport model is developed where the electron channel is dominated by trapped electron modes [4] and the ion channel allows both neoclassical processes and the η_i mode [5]. Coupling between channels is by Coulomb collisions.

A weakness in the microinstability-based models is their apparent failure to predict temperature profiles in detail while the global energy confinement time is fairly well represented. Following Tang, we sidestep this issue by assuming the principle of profile consistency and use Tang's prescription to average the heat flow equations over the "consistent" profiles (gaussian in shape). Solving the equations thus averaged determines the magnitudes of the ion and electron temperatures as a function of input parameters, and from these, the global energy confinement time. The theoretical results are then cast in the form of scaling laws by means of regression analysis similar to that by which the Kaye-Goldston scaling was derived from experimental data.

In part 2, results are compared with recent experiments, and the energy confinement time predicted for TIBER II parameters is compared with TIBER II requirements. Particular attention is given to scaling with electron temperature, rewritten in terms of the power required to maintain that temperature. We also note the sensitivity of results to the assumed radial profiles, which appears as a dependence on the safety factor q_a at the edge (since the consistent profile depends on q_a).

SIGNIFICANCE OF RESULTS

Compared to earlier Engineering Test Reactor designs such as INTOR, the smaller TIBER II design offers significant cost reductions if the underlying assumptions are valid. It is hoped that the present work will shed light on the assumptions about confinement and suggest further experiments and calculations that would increase confidence in extrapolating present experimental results to the reactor regime. Results to date suggest that the scaling with electron temperature (or power) is not more unfavorable than that given by the Kaye-Goldston formula already in use in the TIBER II design work. Numerical results are found to be somewhat sensitive to details of the radial profile.

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